Skid 2227

4770-009

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1829

c1

DATA ON THE COMPRESSIVE STRENGTH OF 75S-T6 ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL EXTRUDED Z-SECTION STIFFENERS

By William A. Hickman and Norris F. Dow

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

Washington
March 1949

3-25-49

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 1829

DATA ON THE COMPRESSIVE STRENGTH OF 75S-T6 ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL EXTRUDED Z-SECTION STIFFENERS

By William A. Hickman and Norris F. Dow

SUMMARY

The experimental results are presented for a part of an investigation of the compressive strength of 75S-T6 aluminum-alloy flat panels with longitudinal extruded Z-section stiffeners. This part of the investigation is concerned with panels in which the ratio of the thickness of the stiffener material to the skin material varies from 0.4 to 1.0 and the ratio of stiffener spacing to skin thickness varies from 15 to 40.

INTRODUCTION

The strength of longitudinally stiffened wing compression panels has been the subject of an extensive study (references 1 to 9) in the Langley Structures Research Laboratory of the National Advisory Committee for Aeronautics. One of the facts brought out by this investigation (see references 7 to 9) is that the structural efficiency of a Z-section stiffener compares very favorably with that of other stiffener shapes. Because of this high structural efficiency and because of the advantages (apart from structural efficiency) inherent in a simple shape like a Z-section, the investigation of stiffened panels has been extended to cover most thoroughly the strength of flat compression panels of 75S-T6 aluminum-alloy with extruded Z-section stiffeners. Inasmuch as the investigation is extensive and the time required to complete the experimental work and to analyze the data will consequently be prolonged, the experimental results, without analysis, are to be presented as they are obtained. In the present paper, the results are presented for panels in which the stiffeners are relatively thick and closely spaced; specifically, for panels for which the ratio of the thickness of the stiffener material to the skin material varies from 0.4 to 1.0 and the ratio of stiffener spacing to skin thickness varies from 15 to 40.

SYMBOLS

Symbols for panel dimensions are identified in figure 1. Other symbols used are defined as follows:

P_i	compressive load per inch of panel width, kips per inch
L	length of panel, inches
c	coefficient of end fixity in Euler column formula
σ_{cy}	compressive yield stress, ksi
σ_{cr}	stress for local buckling of the sheet, ksi
$\bar{\sigma}_f$	average stress at failing load, ksi
$\bar{\epsilon}_f$	shortening per unit length at failing load
p	rivet pitch, inches
d	rivet diameter, inches
ρ	radius of gyration, inches

TEST SPECIMENS AND PROCEDURE

Test specimens.- The test specimens covered by the part of the investigation presented herein consisted of six stiffeners and five bays as shown in figure 1. The stiffeners were riveted to the sheets with large-diameter, closely spaced A17S-T4 flat-head rivets (AN442AD) on all panels. The nominal value of stiffener thickness t_W was held constant at 0.102 inch and, by variation of the sheet thickness t_S, values of t_W/t_S of 0.40, 0.63, and 1.00 were obtained. Five stiffener spacings and four sizes of stiffener corresponding to ratios of stiffener spacing to skin thickness b_S/t_S of 15, 20, 25, 30, and 40 and ratios of stiffener width to thickness b_W/t_W of 12, 20, 30, and 40 were used for each value of t_W/t_S. The dimensions of the test specimens are given in tables 1 to 3.

For each cross section the length of specimen was varied to give five values of slenderness ratio, namely, $\frac{L}{\rho}$ = 20, 35, 55, 85, and 125. Some

 L

$P_{cr} = \frac{\pi^2 EI}{3Kl}$ $K = .5 - 1.0$ $\frac{\pi^2 E}{\left(\frac{Kl}{\rho}\right)^2}$ $K=4$ $K = 1$ to 4

of the panels having $\frac{L}{\rho} = 20$ were so short that the bay width b_S was greater than the length L. The values of the stress for local buckling of the sheet σ_{cr} and of the average stress at failing load $\bar{\sigma}_f$ for these panels are distinguished by placing them in brackets in table 1.

Material properties.- The with-grain compressive yield stress σ_{cy} for the skin material (bare 75S-T6 aluminum-alloy sheet) ranged between 78.9 ksi and 71.3 ksi with an average of 74.6 ksi and that of the stiffener material (extruded 75S-T6 aluminum-alloy) varied between 85.3 ksi and 71.0 ksi with an average of 79.2 ksi.

Testing methods and procedure.- The panels were tested flat-ended, without side support, in the 1,200,000-pound-capacity testing machine at the Langley structures research laboratory. Within the range of loads used, the indicated load on the testing machine was within one-half of 1 percent of the applied load. The ends of the panels were ground accurately flat and parallel in a special grinder, and the method of alinement in the testing machine was such as to insure uniform bearing on the ends of the specimens. Figure 2 shows a panel after failure in the testing machine.

The local-buckling load was determined by the strain-reversal method (reference 10) as the load at which a plot of the strains near the crest of a buckle first shows a decreasing strain with increasing load. The buckling load was divided by the cross-sectional area to give the stress for local buckling σ_{cr}.

The shortening per unit length $\bar{\epsilon}_f$ was measured as the average of the strains indicated by four $6\frac{1}{2}$-inch resistance-type wire strain gages mounted on the quarter points along the length of the second and fifth stiffeners.

Since an end-fixity coefficient c of 3.75 has been indicated for similar panel tests in this machine and because the results of an end-fixity test of the type described in reference 11 on one of the panels of the present investigation (fig. 3) checked this value of c, a value of c = 3.75 was used in reducing the test data.

In order to take into account the fact that the specimens had an unequal number of stiffeners and bays, the test data were adjusted in the manner described in reference 1. This adjustment consisted essentially of subtracting the load carried by one stiffener from the testing machine load. This adjusted load was then divided by the cross-sectional area of the panel minus the area of one stiffener to obtain the average stress, or by the panel width to obtain the load per inch of width.

RESULTS AND DISCUSSION

The results of the investigation, adjusted as previously described for an unequal number of stiffeners and bays, are given in tables 1 to 3 and figures 4 to 6. The tables give values of the ratio of rivet diameter to sheet thickness d/t_S, the ratio of rivet pitch to sheet thickness p/t_S, the unit shortening at failing load $\bar{\epsilon}_f$, the stress for local buckling of the sheet σ_{cr}, and the average stress at failing load $\bar{\sigma}_f$ for corresponding values of the structural index $\frac{P_i}{L/\sqrt{c}}$. (See references 12 and 13.) The figures give plots of $\bar{\sigma}_f$ against $\frac{P_i}{L/\sqrt{c}}$ for the various dimension ratios used.

The same general trends observed in previous investigations (references 6 to 9) are also shown in figures 4 to 6, namely:

(1) At very low values of $\frac{P_i}{L/\sqrt{c}}$ (long panels that fail by column bending), the stress developed by the panels increases with an increase in b_W/t_W because an increase in the web width of the stiffeners provides increased column strength. For high values of $\frac{P_i}{L/\sqrt{c}}$ (short panels that fail by local buckling), however, the stress generally decreases as b_W/t_W increases because an increase in the web width of the stiffeners decreases the local-buckling strength.

(2) Except at very low values of $\frac{P_i}{L/\sqrt{c}}$ (long panels that fail by column bending), the stress developed by the test panels tends to increase as b_S/t_S is decreased because a decrease in the stiffener spacing increases the local-buckling strength.

At the extreme proportions studied in the present investigation (values of b_S/t_S as low as 15 and of b_W/t_W as low as 12), abnormally high values of $\frac{P_i}{L/\sqrt{c}}$, $\bar{\sigma}_f$, and σ_{cr} were obtained. The high values of $\frac{P_i}{L/\sqrt{c}}$ were due both to the high load-carrying ability associated with the close stiffener spacings and to the short lengths associated with the small stiffeners. The short lengths were also undoubtedly responsible for the abnormally high stresses $\bar{\sigma}_f$ and σ_{cr} that were obtained at the wider stiffener spacings. If a short panel, for which the ratio of length to bay width L/b_S approaches 1.0 or less, is tested flat-ended, the test values of $\bar{\sigma}_f$ and σ_{cr} may be expected to be higher than for a panel of the same cross-sectional proportions but having greater length or less end restraint. The end restraints cause interferences with the formation of local buckles which are different from the interferences with bending of the panel as a column, so that division by the $\sqrt{c}$ does not correct the test length to a pin-ended effective length. Until an analysis has been made to evaluate end effects on abnormally short specimens, where local buckling predominates, the high stress values obtained from them should be recognized to be out of line with those obtained for more normally proportioned panels.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va., January 11, 1949

REFERENCES

1. Rossman, Carl A., Bartone, Leonard M., and Dobrowski, Charles V.: Compressive Strength of Flat Panels with Z-Section Stiffeners. NACA ARR No. 4B03, 1944.

2. Lundquist, Eugene E., Kotanchik, Joseph N., and Zender, George W.: A Study of the Compressive Strength of Stiffened Plywood Panels. NACA RB, Aug. 1942.

3. Weinberger, Robert A., Sperry, William C., and Dobrowski, Charles V.: Compressive Strength of Corrugated-Sheet-Stiffened Panels for the Consolidated XB-36 Airplane. NACA MR, Jan. 28, 1944.

4. Kotanchik, Joseph N., Weinberger, Robert A., Zender, George W., and Neff, John, Jr.: Compressive Strength of Flat Panels with Z- and Hat-Section Stiffeners. NACA ARR No. L4F01, 1944.

5. Dow, Norris F., Hickman, William A., and McCracken, Howard L.: Compressive-Strength Comparisons of Panels Having Aluminum-Alloy Sheet and Stiffeners with Panels Having Magnesium-Alloy Sheet and Aluminum-Alloy Stiffeners. NACA TN No. 1274, 1947.

6. Hickman, William A., and Dow, Norris F.: Compressive Strength of 24S-T Aluminum-Alloy Flat Panels with Longitudinal Formed Hat-Section Stiffeners Having Four Ratios of Stiffener Thickness to Skin Thickness. NACA TN No. 1553, 1948.

7. Schuette, Evan H., Barab, Saul, and McCracken, Howard L.: Compressive Strength of 24S-T Aluminum-Alloy Flat Panels with Longitudinal Formed Hat-Section Stiffeners. NACA TN No. 1157, 1946.

8. Hickman, William A., and Dow, Norris F.: Compressive Strength of 24S-T Aluminum-Alloy Flat Panels with Longitudinal Formed Hat-Section Stiffeners Having a Ratio of Stiffener Thickness to Skin Thickness Equal to 1.00. NACA TN No. 1439, 1947.

9. Dow, Norris F., and Hickman, William A.: Design Charts for Flat Compression Panels Having Longitudinal Extruded Y-Section Stiffeners and Comparison with Panels Having Formed Z-Section Stiffeners. NACA TN No. 1389, 1947.

10. Hu, Pai C., Lundquist, Eugene E., and Batdorf, S. B.: Effect of Small Deviations from Flatness on Effective Width and Buckling of Plates in Compression. NACA TN No. 1124, 1946.

11. Schuette, Evan H., and Roy, J. Albert: The Determination of Effective Column Length from Strain Measurements. NACA ARR No. L4F24, 1944.

12. Zahorski, Adam: Effects of Material Distribution on Strength of Panels. Jour. Aero. Sci., vol. 11, no. 3, July 1944, pp. 247-253.

13. Schuette, Evan H.: Charts for the Minimum-Weight Design of 24S-T Aluminum-Alloy Flat Compression Panels with Longitudinal Z-Section Stiffeners. NACA Rep. No. 827, 1945.

TABLE 1

TEST DATA AND PROPORTIONS OF SPECIMENS HAVING $\frac{t_W}{t_S} = 0.40$

$\left[\frac{r}{t_W} = 0.92;\ \frac{d}{t_S} = 1.75;\ \frac{p}{t_S} = 5.00\right]$

Proportions of test specimens[a]							Test data			
t_W (in.)	$\frac{t_W}{t_S}$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{t_W}$	$\frac{b_A}{t_W}$	$\frac{L}{b_W}$ (b)	σ_{cr} (ksi)	$\overline{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)	$\overline{\epsilon}_f$
(0.102)	(0.40)	(15)	(12)	(4.7)	(12.7)					
0.1012	0.408	15.1	12.2	4.70	12.81	6.0	69.3	72.5	6.36	755×10^{-5}
.1006	.404	15.1	12.2	4.83	12.98	10.5	----	70.6	3.54	744
.1008	.406	15.1	12.4	4.52	12.95	16.2	----	61.9	1.98	571
.0997	.400	14.9	12.2	4.77	12.95	25.9	----	44.2	.90	393
.1032	.416	15.1	11.8	4.61	12.56	38.2	----	15.6	.21	160
			(20)	(7.9)						
.1020	.407	15.1	20.2	7.81	12.66	6.6	----	67.9	3.52	730
.1023	.414	15.2	20.0	7.90	12.67	11.6	----	64.7	1.89	667
.1018	.410	15.1	20.1	7.91	12.78	18.3	----	61.3	1.14	548
.1016	.403	14.9	20.1	8.03	12.85	28.4	----	43.8	.53	411
.0981	.394	15.1	20.9	8.24	13.21	41.7	----	19.1	.16	185
			(30)	(11.9)						
.1016	.410	15.2	30.3	11.92	13.05	7.2	----	57.2	1.93	751
.1011	.410	15.3	30.2	11.91	12.72	12.7	----	48.2	.96	480
.1023	.416	15.3	30.0	11.67	12.57	19.9	----	45.2	.58	401
.1012	.407	15.1	30.4	11.75	12.71	30.8	----	37.4	.31	351
.1007	.406	15.2	30.3	12.00	12.27	45.4	----	21.2	.12	198
			(40)	(15.9)						
.1030	.419	15.2	39.7	15.79	12.53	7.6	----	48.2	1.33	511
.1004	.402	15.1	40.8	16.10	12.86	13.2	----	43.4	.69	426
.1027	.413	15.2	39.9	15.77	12.20	20.9	----	31.9	.32	339
.1011	.405	15.1	40.3	16.01	12.72	32.4	----	29.3	.19	272
.1007	.406	15.1	40.3	16.14	12.67	47.0	----	19.6	.09	180
		(20)	(12)	(4.7)						
.1002	.406	20.4	12.4	4.81	12.58	4.7	65.0	72.0	7.50	694
.1016	.409	20.1	12.0	4.70	12.75	9.7	----	68.4	3.50	670
.1012	.405	20.1	12.2	4.85	13.04	14.9	----	60.6	1.99	629
.1017	.411	20.2	12.2	4.83	12.81	21.3	----	39.7	.84	374
.1015	.406	20.1	12.1	4.73	12.72	34.5	----	20.0	.29	189
			(20)	(7.9)						
.1020	.417	20.4	20.2	7.82	12.61	6.0	66.9	68.2	3.57	674
.1021	.413	20.3	20.1	8.01	12.90	10.6	----	64.7	1.93	613
.1020	.412	20.2	20.1	7.91	12.90	16.9	----	61.0	1.14	582
.1015	.407	20.1	20.1	8.06	12.91	26.3	----	43.5	.53	400
.1018	.410	20.2	20.2	7.95	12.70	38.4	----	24.8	.20	230
			(30)	(11.9)						
.1012	.407	20.1	30.4	12.02	12.97	6.7	55.2	56.7	1.95	540
.1004	.405	20.3	30.4	12.02	12.91	11.9	----	51.6	1.00	490
.1017	.411	20.1	30.2	11.84	12.61	18.6	----	44.3	.55	416
.1005	.405	20.2	30.6	11.93	12.82	28.7	----	36.9	.30	352
.1016	.410	20.2	30.1	11.98	12.75	42.5	----	23.4	.12	268
			(40)	(15.9)						
.1008	.408	20.3	41.0	16.26	12.94	7.1	49.8	50.8	1.32	553
.0983	.396	20.2	41.7	16.41	13.23	12.6	----	43.8	.65	428
.1018	.410	20.0	40.2	15.94	12.61	19.8	----	36.4	.34	384
.1019	.408	20.0	40.1	15.82	12.60	30.8	----	29.8	.18	278
.1007	.408	20.4	40.7	16.11	12.95	45.1	----	20.0	.08	190
		(25)	(12)	(4.7)						
.1018	.409	25.1	12.3	4.75	12.78	4.6	58.6	65.3	6.58	639
.1017	.406	24.9	12.1	4.68	12.74	8.0	56.2	61.5	3.65	617
.1054	.423	25.2	11.7	4.51	12.29	13.8	----	55.2	1.87	500
.1009	.407	25.2	12.1	4.80	12.95	21.7	----	38.9	.85	350
.1014	.407	25.0	12.1	4.72	12.63	31.9	----	13.0	.23	160
			(20)	(7.9)						
.1016	.407	25.0	20.3	7.76	12.75	5.5	54.9	61.9	3.36	630
.1013	.406	25.0	20.0	7.96	12.99	9.9	58.4	59.8	1.84	550
.0982	.394	25.0	20.9	8.21	13.20	15.7	56.7	58.9	1.13	540
.0987	.396	25.0	20.7	8.17	13.03	24.4	----	46.0	.57	420
.1000	.400	25.0	20.4	8.16	12.86	35.9	----	21.8	.18	200

L'	L/ρ
6.32	8.1
11.15	14.3
17.80	22.8
27.70	35.5
40.4	51.8

[a]Nominal proportions are given in parentheses.
[b]Lengths are for actual test specimens for which $c \approx 3.75$.

NACA

TABLE 1.– Concluded

TEST DATA AND PROPORTIONS OF SPECIMENS HAVING $\frac{t_W}{t_S}$ = 0.40 – Concluded

Proportions of test specimens[a]							Test data			
t_W (in.)	$\frac{t_W}{t_S}$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{t_W}$	$\frac{b_A}{t_W}$	$\frac{L}{b_W}$ (b)	σ_{cr} (ksi) (c)	$\bar{\sigma}_f$ (ksi) (c)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\bar{\epsilon}_f$
(0.102)	(0.40)	(25)	(30)	(11.9)	(12.7)					
0.1001	0.404	25.2	30.3	12.13	13.15	6.3	51.5	56.0	1.92	490×10^{-5}
.1003	.406	25.2	30.4	11.97	12.92	11.1	----	50.7	.98	466
.1028	.418	25.4	29.6	11.54	13.13	17.6	----	46.2	.57	450
.1013	.406	25.0	30.2	11.76	12.69	27.1	----	43.5	.35	390
.1018	.407	24.9	30.2	11.85	12.73	39.8	----	25.4	.14	240
			(40)	(15.9)						
.1002	.404	25.2	40.9	16.16	12.93	6.8	46.6	49.6	1.26	460
.1026	.411	25.1	39.8	15.79	12.53	11.9	----	42.3	.62	420
.1040	.416	25.0	39.1	15.57	12.66	18.9	----	34.6	.32	320
.1053	.422	24.9	38.9	15.20	12.26	29.0	----	28.9	.17	280
.1032	.411	25.0	39.7	15.64	12.36	42.6	----	21.1	.09	210
		(30)	(12)	(4.7)						
.1019	.411	30.1	12.2	4.72	12.79	4.4	[52.0]	[59.5]	6.20	
.1009	.410	30.2	12.1	4.71	12.80	7.9	40.5	55.3	2.84	730
.1011	.410	30.2	12.1	4.73	12.81	12.9	43.2	47.1	1.69	430
.1014	.411	30.5	12.0	4.80	12.73	20.3	----	32.7	.75	310
.1018	.413	30.1	12.1	4.72	12.75	29.7	----	23.7	.36	210
			(20)	(7.9)						
.0986	.406	30.1	20.1	8.11	13.18	8.2	40.6	55.2	3.01	630
.1020	.412	30.1	20.0	7.90	12.92	9.2	41.4	50.7	1.60	640
.1018	.410	30.0	20.0	7.89	12.72	14.8	43.0	49.3	.97	510
.0985	.392	30.3	21.0	8.10	13.10	22.7	----	44.8	.57	400
.0988	.401	30.1	21.0	8.20	13.11	33.6	----	20.8	.18	190
			(30)	(11.9)						
.1014	.405	30.4	30.1	11.89	12.68	6.0	43.9	47.6	1.62	650
.1007	.403	30.5	31.2	12.03	12.87	10.4	41.5	45.9	.91	460
.1013	.409	30.1	30.2	11.95	12.79	16.6	----	44.8	.55	400
.1010	.409	30.2	30.1	11.92	12.74	25.7	----	39.6	.32	350
.1016	.409	30.0	30.2	11.87	12.66	37.9	----	25.9	.14	241
			(40)	(15.9)						
.1007	.399	29.8	40.1	16.07	13.02	6.5	38.7	46.1	1.18	450
.1015	.417	31.0	40.2	15.95	12.77	11.4	40.5	43.7	.62	390
.1005	.407	30.6	41.1	16.15	12.89	17.9	----	39.3	.35	350
.1028	.416	30.1	40.0	15.72	12.51	27.4	----	29.4	.17	280
.1050	.422	30.2	39.8	15.41	12.31	40.4	----	22.0	.09	210
		(40)	(12)	(4.7)						
.1028	.413	40.9	12.0	4.84	12.81	4.1	[41.1]	[57.2]	6.27	500
.1004	.407	40.6	11.9	4.81	12.82	7.7	[31.4]	[42.6]	2.53	555
.1001	.403	40.2	12.3	4.90	12.81	11.8	24.3	46.0	1.73	500
.1018	.411	40.3	12.1	4.72	12.67	17.7	23.0	26.5	.66	240
.1007	.407	40.4	12.2	4.85	12.81	26.7	----	20.4	.34	188
			(20)	(7.9)						
.0988	.398	40.3	20.8	8.23	13.13	4.8	[29.4]	[47.8]	2.75	808
.0986	.398	40.3	20.8	8.22	13.23	8.4	22.6	43.4	1.43	520
.0978	.394	40.3	20.8	8.20	13.31	13.3	23.5	39.1	.82	520
.0991	.400	40.4	20.7	8.21	13.12	20.6	24.7	33.7	.45	340
.0977	.402	40.3	20.7	8.20	13.60	30.9	----	15.5	.14	144
			(30)	(11.9)						
.1008	.410	40.7	30.2	12.50	13.50	5.5	23.3	41.4	1.40	520
.1016	.406	40.0	30.2	11.81	12.70	9.6	23.2	37.6	.76	530
.1009	.406	40.2	30.3	11.91	12.81	15.2	24.3	35.9	.46	450
.1010	.409	40.5	30.4	11.91	12.82	23.3	24.4	34.2	.28	330
.0999	.405	40.7	30.8	12.06	13.01	34.3	-----	21.7	.12	200
			(40)	(15.9)						
.1003	.404	40.3	40.9	16.25	13.03	5.9	23.4	38.6	.99	560
.1020	.411	40.3	41.1	16.33	12.69	10.4	24.4	35.1	.52	450
.1027	.415	40.4	40.0	16.47	12.54	16.4	24.9	32.5	.30	304
.1004	.403	40.1	40.6	16.31	13.12	25.5	25.0	26.8	.16	290
.1011	.407	40.3	40.3	16.02	12.73	37.6	----	21.9	.09	177

[a]Nominal proportions are given in parentheses.
[b]Lengths are for actual test specimens for which c ≈ 3.75.
[c]Bracketed values are for panels having bay width b_S greater than length L.

NACA

$t_s = .16$

TABLE 2

TEST DATA AND PROPORTIONS OF SPECIMENS HAVING $\frac{t_W}{t_S} = 0.63$

$\left[\frac{r}{t_W} = 0.92;\ \frac{d}{t_S} = 2.00;\ \frac{p}{t_S} = 6.41\right]$

Proportions of test specimens[a]							Test data			
t_W (in.)	$\frac{t_W}{t_S}$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{t_W}$	$\frac{b_A}{t_W}$	$\frac{L}{b_W}$ (b)	σ_{cr} (ksi)	$\bar{\sigma}_f$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\bar{\epsilon}_f$
(0.102)	(0.63)	(15)	(12)	(4.7)	(9.7)					
0.0978	0.627	15.0	12.5	4.81	10.01	7.4	----	73.7	4.90	936×10^{-5}
.1020	.665	15.3	12.1	4.79	9.68	12.7	----	67.5	2.30	995
.1018	.658	15.1	12.2	4.59	9.67	20.1	----	60.1	1.30	576
.1015	.663	15.4	12.1	4.71	9.51	31.4	----	46.3	.64	426
.1031	.658	15.1	11.9	4.60	9.65	46.1	----	19.7	.19	188
			(20)	(7.9)						
.0988	.643	15.5	20.7	8.01	9.93	7.9	----	69.0	2.63	706
.0989	.639	15.0	20.6	8.10	9.92	13.9	----	64.2	1.42	663
.0998	.641	15.1	20.5	8.11	9.62	21.7	----	60.3	.84	576
.1002	.655	15.4	20.3	7.95	9.91	33.7	----	39.9	.36	375
.0997	.652	15.3	20.3	8.01	9.90	49.8	----	19.5	.12	191
			(30)	(11.9)						
.1019	.664	15.4	30.3	11.87	9.70	8.1	----	49.0	1.45	510
.1019	.650	14.9	30.0	11.86	9.70	14.4	----	46.5	.81	462
.1017	.663	15.4	30.2	11.96	9.71	22.5	----	44.3	.48	437
.1016	.661	15.3	30.1	11.84	9.81	34.8	----	29.2	.23	293
.1013	.656	15.1	30.2	11.91	9.60	51.3	----	15.9	.08	156
			(40)	(15.9)						
.1037	.669	15.1	39.3	15.53	9.75	8.3	----	42.2	1.08	508
.1035	.677	15.2	40.1	15.60	9.54	14.3	----	36.4	.54	419
.1038	.676	15.4	39.6	15.61	9.47	22.6	----	30.6	.28	348
.1039	.680	15.3	39.5	15.61	9.38	35.0	----	22.2	.14	221
.1031	.660	14.9	39.7	15.74	9.62	46.5	----	15.6	.07	148
		(20)	(12)	(4.7)						
.0984	.640	20.4	12.5	4.91	9.81	7.0	----	69.9	3.84	826
.1022	.677	20.3	12.0	4.75	9.54	12.2	----	69.8	2.22	729
.1026	.668	20.3	12.1	4.75	9.55	19.0	----	58.1	1.18	580
.1010	.664	20.6	12.0	4.74	9.75	30.0	----	45.5	.59	436
.0997	.656	20.6	12.3	4.80	9.96	43.6	----	24.4	.21	237
			(20)	(7.9)						
.0978	.640	20.4	21.0	8.21	10.03	7.6	----	69.5	2.39	676
.0977	.640	20.4	20.9	8.31	10.04	13.3	----	64.7	1.29	616
.1001	.655	20.5	20.4	8.01	9.79	20.9	----	58.4	.74	482
.0997	.654	20.7	20.6	8.11	10.01	32.1	----	46.7	.38	404
.0995	.641	20.2	20.4	8.00	9.98	47.9	----	21.7	.12	203
			(30)	(11.9)						
.1015	.671	20.5	30.5	12.01	9.71	7.9	----	51.5	1.34	514
.1021	.659	20.3	30.0	11.72	9.71	14.0	----	45.9	.68	462
.1002	.659	20.6	30.7	12.01	9.72	21.9	----	46.0	.43	428
.1017	.670	20.4	30.2	11.97	9.80	33.9	----	33.4	.20	308
.1000	.659	20.7	30.7	12.10	9.72	50.0	----	19.4	.08	178
			(40)	(15.9)						
.1038	.687	20.6	40.2	15.51	9.37	8.2	----	43.1	.94	532
.1033	.683	20.6	39.7	15.61	9.48	14.3	----	36.0	.45	407
.1046	.694	20.8	39.3	15.52	9.44	22.5	----	32.3	.26	322
.1046	.672	20.2	39.1	15.37	9.23	34.8	----	26.6	.14	252
.1042	.689	20.6	39.3	15.61	9.31	46.6	----	19.1	.07	179
		(25)	(12)	(4.7)						
.0986	.631	25.1	12.6	4.83	9.80	6.6	61.5	65.3	3.56	748
.1023	.666	25.3	12.0	4.65	9.54	11.5	59.1	64.1	2.02	615
.1030	.664	25.2	11.9	4.60	9.28	18.2	----	62.9	1.25	594
.0988	.644	25.4	12.3	4.75	9.63	28.3	----	48.7	.62	454
.1008	.653	25.4	12.0	4.82	9.73	41.9	----	24.7	.22	240
			(20)	(7.9)						
.1016	.653	25.0	20.2	7.93	9.70	7.2	61.2	62.8	2.12	672
.0980	.634	25.2	20.8	8.12	10.01	12.8	61.2	63.5	1.20	609
.0998	.646	25.2	20.4	8.08	9.78	20.1	----	60.6	.73	560
.0993	.642	25.3	20.6	8.07	9.98	30.9	----	44.7	.35	418
.0998	.650	25.4	20.4	7.96	9.78	45.8	----	23.7	.12	228

[a]Nominal proportions are given in parentheses.
[b]Lengths are for actual test specimens for which $c \approx 3.75$.

NACA

TABLE 2.– Concluded

TEST DATA AND PROPORTIONS OF SPECIMENS HAVING $\frac{t_W}{t_S} = 0.63$ – Concluded

Proportions of test specimens[a]							Test data			
t_W (in.)	$\frac{t_W}{t_S}$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{t_W}$	$\frac{b_A}{t_W}$	$\frac{L}{b_W}$ (ksi)	σ_{cr} (ksi)	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)	$\bar{\epsilon}_f$
(0.102)	(0.63)	(25)	(30)	(11.9)	(9.7)					
0.1002	0.654	25.5	30.7	11.94	9.74	7.7	48.4	51.6	1.24	510×10^{-5}
.1012	.655	25.3	30.3	11.92	9.74	13.6	----	46.4	.63	445
.1013	.653	25.1	30.2	11.91	9.73	21.4	----	44.8	.39	414
.1004	.646	25.0	30.7	12.04	9.87	32.8	----	38.8	.22	362
.1005	.646	25.0	30.7	12.03	9.71	48.2	----	21.9	.08	199
			(40)	(15.9)						
.1027	.657	25.0	40.0	15.71	9.60	8.0	42.0	43.7	.87	513
.1071	.679	24.8	38.3	15.16	9.30	14.0	39.4	40.0	.45	468
.1013	.654	25.2	40.3	16.01	9.73	22.1	----	35.1	.25	358
.1026	.666	25.4	39.7	15.71	9.51	34.2	----	27.3	.12	265
.1048	.673	25.2	38.9	15.45	9.12	46.9	----	21.6	.07	195
		(30)	(12)	(4.7)						
.0983	.639	31.1	12.5	4.94	9.92	6.3	44.1	58.3	3.14	650
.0972	.628	30.1	12.7	4.99	9.94	10.9	44.6	53.8	1.65	672
.1009	.650	30.0	12.0	4.72	9.47	17.4	46.1	52.8	1.04	584
.1038	.673	30.2	11.7	4.59	9.45	26.8	----	43.1	.55	415
.0997	.642	30.2	12.3	4.77	10.48	39.1	----	24.8	.22	227
			(20)	(7.9)						
.1018	.656	30.3	20.0	7.94	9.58	7.0	48.4	54.8	1.78	647
.0991	.635	30.2	20.5	8.03	9.70	12.2	47.4	53.0	.99	648
.0978	.627	30.4	20.9	8.14	10.03	19.2	48.8	53.5	.63	567
.1004	.646	30.1	20.2	8.05	9.77	29.9	----	47.4	.36	444
.0991	.641	30.0	20.5	8.06	9.95	44.0	----	25.9	.13	242
			(30)	(11.9)						
.1009	.656	30.0	30.6	11.95	9.77	7.5	43.6	47.7	1.08	480
.1016	.654	30.1	30.2	11.86	9.65	13.2	44.9	46.0	.60	442
.1010	.652	30.1	30.2	11.84	9.61	20.8	----	43.3	.36	400
.1004	.654	31.4	30.6	11.99	9.87	32.0	----	39.9	.21	380
.1014	.649	30.2	30.4	11.84	9.72	47.1	----	23.2	.08	216
			(40)	(15.9)						
.1044	.671	30.0	39.0	15.48	9.35	10.4	33.0	41.9	.77	515
.1008	.656	31.0	40.5	16.17	9.73	13.8	32.0	38.2	.40	453
.1055	.676	30.5	38.9	15.25	9.44	21.5	31.9	35.4	.24	354
.1015	.657	30.4	39.4	15.41	9.38	33.2	----	27.4	.12	275
.1033	.664	30.1	39.5	15.67	9.45	46.8	----	20.7	.06	193
		(40)	(12)	(4.7)						
.0992	.649	40.7	12.4	4.89	9.94	5.6	29.6	51.6	2.88	750
.0976	.644	41.2	12.6	4.90	9.90	10.1	24.1	46.0	1.42	738
.1011	.661	41.0	12.2	4.78	9.51	15.7	23.9	44.6	.89	598
.0998	.654	41.3	12.3	4.82	9.92	24.6	26.0	37.3	.48	431
.0990	.653	41.1	12.3	4.91	9.91	36.3	----	23.0	.20	220
			(20)	(7.9)						
.1011	.665	41.0	20.2	7.92	9.60	6.5	25.7	48.1	1.52	650
.0999	.650	41.7	20.5	8.00	9.90	11.4	26.0	44.5	.80	720
.0986	.645	40.9	20.7	8.21	9.91	17.9	26.3	44.3	.51	620
.0991	.652	41.1	20.6	8.11	9.91	27.8	27.6	39.4	.30	430
.0994	.651	40.9	20.6	8.32	9.91	40.7	----	24.3	.12	230
			(30)	(11.9)						
.1003	.657	41.0	30.5	12.01	9.72	7.1	24.9	42.4	.91	450
.1021	.666	40.9	30.1	11.82	9.62	12.4	27.1	39.4	.47	690
.1010	.660	40.9	30.2	11.87	9.81	19.6	26.6	37.0	.29	390
.1011	.646	39.9	30.4	11.84	9.80	30.3	27.0	35.9	.18	420
.1012	.664	40.8	30.4	11.91	9.71	44.5	----	23.9	.08	230
			(40)	(15.9)						
.1025	.673	41.2	40.1	15.90	9.60	7.5	24.2	35.9	.60	474
.1027	.676	41.1	39.9	15.85	9.60	13.1	24.5	34.4	.32	680
.1040	.687	41.3	39.7	15.57	9.31	20.6	26.4	31.0	.19	350
.1043	.688	40.9	39.0	15.41	9.32	32.1	25.5	27.0	.11	230
.1034	.678	40.9	39.6	15.60	9.61	46.6	----	21.7	.06	200

[a]Nominal proportions are given in parentheses.
[b]Lengths are for actual test specimens for which $c \approx 3.75$.

NACA

TABLE 3

TEST DATA AND PROPORTIONS OF STIFFENERS HAVING $\frac{t_W}{t_S} = 1.00$

$$\left[\frac{r}{t_W} = 0.92;\ \frac{d}{t_S} = 1.84;\ \frac{p}{t_S} = 6.13\right]$$

Proportions of test specimens[a]							Test data			
t_W (in.)	$\frac{t_W}{t_S}$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{t_W}$	$\frac{b_A}{t_W}$	$\frac{L}{b_W}$ (b)	σ_{cr} (ksi)	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)	$\bar{\epsilon}_f$
(0.102)	(1.00)	(15)	(12)	(4.7)	(6.7)					
0.0985	0.962	15.6	12.6	4.91	6.91	8.1	----	74.6	3.78	943×10^{-5}
.0985	.948	14.7	12.4	4.90	6.90	14.4	----	70.4	2.05	820
.1025	1.022	15.4	11.9	4.78	6.68	22.8	----	65.9	1.22	650
.0978	.969	15.1	12.7	4.92	6.95	34.7	----	45.1	.53	410
.0988	.971	15.4	12.5	4.81	6.82	51.1	----	21.3	.17	200
			(20)	(7.9)						
.0991	.983	15.4	20.6	8.20	6.87	8.4	----	68.9	2.58	730
.1004	.979	15.4	20.3	8.10	6.71	14.7	----	63.8	1.37	580
.1016	.991	15.1	20.1	7.81	6.63	23.1	----	55.4	.77	510
.1000	1.002	15.4	20.6	8.02	6.79	35.3	----	31.5	.28	310
.1021	.994	14.9	20.5	8.04	6.74	51.1	----	18.1	.11	170
			(30)	(11.9)						
.1010	.978	14.5	30.2	11.97	6.85	8.4	----	49.4	1.65	490
.1021	1.003	15.0	29.8	11.83	6.70	14.6	----	44.8	.90	410
.1010	1.005	15.5	30.4	12.01	6.91	22.8	----	39.4	.47	330
.1009	.981	14.9	30.4	11.90	6.79	35.3	----	20.9	.16	275
.1010	.982	14.9	30.3	11.81	6.81	51.8	----	11.0	.06	120
		(20)	(12)	(4.7)						
.0974	.942	20.1	12.6	4.88	6.73	8.0	----	75.2	3.32	870
.0987	.963	20.2	12.5	4.92	6.85	13.9	----	68.1	1.72	750
.0977	.952	20.4	12.6	4.87	6.92	22.0	----	67.3	1.06	600
.0981	.945	20.2	12.4	5.05	6.89	34.3	----	49.5	.52	460
.0986	.948	20.1	12.4	4.93	6.75	50.4	----	25.6	.18	200
			(20)	(7.9)						
.1005	.966	20.0	20.2	8.01	6.62	8.4 17.12	~~----~~ 9.84	70.1	2.21	670
.1007	.978	20.1	20.5	8.10	6.71	14.4 29.4	~~----~~ 15.18	65.8	1.19	620
.1016	.961	19.8	20.1	6.95	6.65	22.8 46.5	~~----~~ 7.4	56.0	.65	470
.1020	.979	20.1	20.1	7.90	6.63	35.0 71.4	~~----~~ 36.85	37.7	.28	340
.1018	.988	20.0	19.9	7.92	6.64	52.4 107.	~~----~~ 55.2	20.6	.10	200
			(30)	(11.9)						
.1006	.995	20.4	30.3	12.05	6.82	8.4	----	48.2	1.29	578
.1001	.967	20.2	30.7	12.15	6.75	14.6	----	46.3	.71	570
.1011	.975	20.1	30.4	11.98	6.69	22.8	----	40.4	.39	400
.1007	.995	20.1	30.2	12.03	6.51	35.6	----	25.6	.16	290
.1013	.983	20.0	29.9	11.91	6.67	52.6	----	14.4	.06	120
			(40)	(15.9)						
.1032	1.004	20.1	39.2	15.85	6.65	8.4	----	40.9	.99	510
.1052	1.016	20.1	38.9	15.26	6.33	14.4	----	38.0	.54	500
.1037	.999	20.2	39.1	15.58	6.42	22.9	----	30.5	.27	310
.1031	.979	20.4	39.4	15.70	6.55	35.2	----	18.5	.12	210
.1032	1.013	20.0	39.5	15.65	6.50	46.8	----	12.2	.05	110
		(25)	(12)	(4.7)						
.0985	.978	24.9	12.5	4.95	6.89	7.8	62.3	70.5	2.88	700
.0981	.938	24.2	12.5	5.63	6.72	13.7	----	67.8	1.60	690
.0988	.975	25.0	12.3	4.81	6.80	21.7	----	66.3	.97	665
.0985	.941	24.3	12.5	4.90	6.80	33.1	----	51.5	.49	460
.0993	.960	25.0	12.3	4.71	6.83	49.3	----	24.4	.16	280
			(20)	(7.9)						
.1005	.964	24.4	20.4	8.14	6.71	8.2	----	69.4	1.96	680
.0985	.963	25.1	21.1	8.05	6.72	14.1	----	64.7	1.04	650
.1022	.989	24.5	20.2	7.81	6.55	22.3	----	55.9	.57	500
.0997	.981	25.0	20.8	7.94	6.63	34.3	----	41.5	.27	380
.1006	.982	25.0	20.4	8.00	6.51	51.0	----	22.8	.10	210

[a]Nominal proportions are given in parentheses.
[b]Lengths are for actual test specimens for which $c \approx 3.75$.

NACA

TABLE 3.– Concluded

TEST DATA AND PROPORTIONS OF STIFFENERS HAVING $\frac{t_W}{t_S} = 1.00$ – Concluded

Proportions of test specimens[a]							Test data			
t_W (in.)	$\frac{t_W}{t_S}$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{t_W}$	$\frac{b_A}{t_W}$	$\frac{L}{b_W}$ (b)	σ_{cr} (ksi)	$\bar{\sigma}_f$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\bar{\epsilon}_f$
(0.102)	(1.00)	(25)	(30)	(11.9)	(6.7)					
0.1008	0.974	25.0	30.3	11.94	6.60	8.4	47.5	52.2	1.19	490×10^{-5}
.1024	1.001	25.0	30.3	12.85	6.57	14.4	----	47.9	.63	450
.1004	1.005	25.5	30.4	12.04	6.76	23.0	----	43.4	.36	420
.1006	.960	24.3	30.1	12.04	6.61	35.8	----	29.0	.16	320
.1006	.980	24.8	30.4	11.98	6.80	52.1	----	17.1	.06	160
			(40)	(15.9)						
.1055	1.020	24.7	38.5	15.37	6.31	8.3	----	41.2	.86	525
.1024	.996	24.7	39.9	15.86	6.50	14.5	----	35.7	.42	400
.1054	1.015	24.5	39.1	15.51	6.51	22.8	----	34.5	.24	360
.1042	1.019	24.9	39.4	15.52	6.40	35.1	----	23.9	.12	220
.1040	1.018	24.8	39.5	15.60	6.51	46.5	----	14.8	.06	160
		(30)	(12)	(4.7)						
.0977	.957	29.5	12.7	4.90	6.91	7.5	57.3	61.2	2.35	800
.0982	.946	29.1	12.6	4.90	6.80	13.2	54.0	59.4	1.31	720
.0887	.851	29.6	13.8	5.49	7.60	20.8	----	59.7	.84	590
.0982	.952	29.7	12.6	4.91	6.91	32.2	----	52.5	.47	480
.0979	.944	29.3	12.4	4.92	6.85	47.8	----	24.4	.15	240
			(20)	(7.9)						
.1024	.998	29.6	20.0	7.87	6.78	8.1	54.6	60.0	1.56	660
.1003	.973	29.4	20.4	7.96	6.64	14.1	56.4	58.0	.86	560
.1016	.970	29.3	20.3	7.83	6.63	22.1	55.8	57.7	.55	520
.0993	.960	29.6	20.5	7.90	6.71	34.4	----	42.0	.26	400
.0988	.941	29.4	20.6	8.20	6.62	50.6	----	22.7	.09	230
			(30)	(11.9)						
.1021	.985	29.7	30.9	11.71	6.62	8.3	42.1	48.1	.99	520
.0998	.970	29.5	30.7	12.15	6.71	14.5	43.4	44.9	.53	450
.1019	.987	29.7	30.2	11.93	6.63	22.7	41.9	42.9	.32	420
.1006	.984	29.8	30.3	12.00	6.64	35.3	----	31.4	.15	310
.1011	.979	29.4	30.3	11.91	6.77	51.6	----	19.2	.06	180
			(40)	(15.9)						
.1042	1.012	29.7	39.0	15.40	6.75	8.3	37.0	40.3	.74	455
.1033	.980	29.2	39.8	15.64	6.57	14.4	31.4	37.4	.40	400
.1052	1.001	29.2	38.9	15.43	6.33	22.7	----	32.6	.22	330
.1050	1.010	29.5	39.0	15.41	6.41	35.2	----	24.0	.10	230
.1043	1.001	29.1	39.1	15.40	6.56	46.9	----	16.7	.06	180
		(40)	(12)	(4.7)						
.0980	.963	39.6	12.5	4.83	6.70	6.8	33.3	52.3	2.00	856
.0989	.953	39.2	12.5	4.92	6.80	12.3	31.4	51.6	1.08	684
.0984	.951	39.7	12.6	4.81	6.81	19.6	33.4	49.4	.65	570
.0991	.957	39.6	12.4	5.00	6.82	30.5	32.6	43.2	.37	469
.0987	.962	39.8	12.5	4.81	6.84	44.5	----	25.7	.15	240
			(20)	(7.9)						
.1017	.981	39.3	20.2	7.91	6.65	7.8	33.8	53.0	1.24	598
.0995	.963	39.3	20.6	8.10	6.90	13.6	32.5	51.6	.66	644
.1013	.981	39.4	20.2	7.95	6.69	21.4	34.5	48.2	.41	544
.0999	.966	39.2	20.4	7.94	6.87	33.2	33.0	40.3	.22	406
.0989	.952	38.9	20.7	8.00	6.70	48.7	----	25.7	.10	230
			(30)	(11.9)						
.1007	.979	39.3	30.3	12.00	6.71	8.2	32.4	42.3	.76	513
.1010	.981	39.8	30.4	11.98	6.67	14.2	30.8	40.4	.41	448
.1013	.984	39.7	30.3	11.79	6.86	22.4	32.8	39.3	.26	437
.1007	.969	39.2	30.3	12.17	6.84	34.7	30.7	32.7	.14	285
.1014	.992	39.6	30.1	11.82	6.63	51.2	----	20.9	.06	200
			(40)	(15.9)						
.1050	1.020	39.8	39.2	15.46	6.52	8.2	25.8	35.6	.55	520
.1054	1.010	39.3	38.7	15.45	6.48	14.5	24.7	33.2	.29	428
.1067	1.011	39.0	38.3	15.23	6.29	22.7	25.6	31.6	.17	408
.1065	1.036	39.6	38.5	15.37	6.41	34.9	23.5	26.6	.10	218
.1040	1.004	39.2	39.2	15.41	6.50	46.8	----	19.5	.05	200

[a]Nominal proportions are given in parentheses.
[b]Lengths are for actual test specimens for which $c \approx 3.75$.

L' = 8.34
Approx ρ = .83
Approx ρ = .823
L' 8.25 14.4 22.6 34.9 51.5

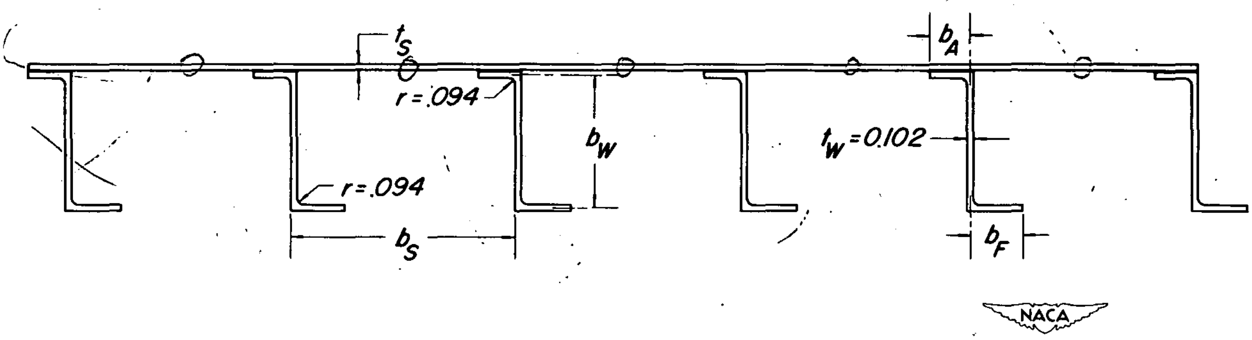

Figure 1.— Cross section of test specimens.

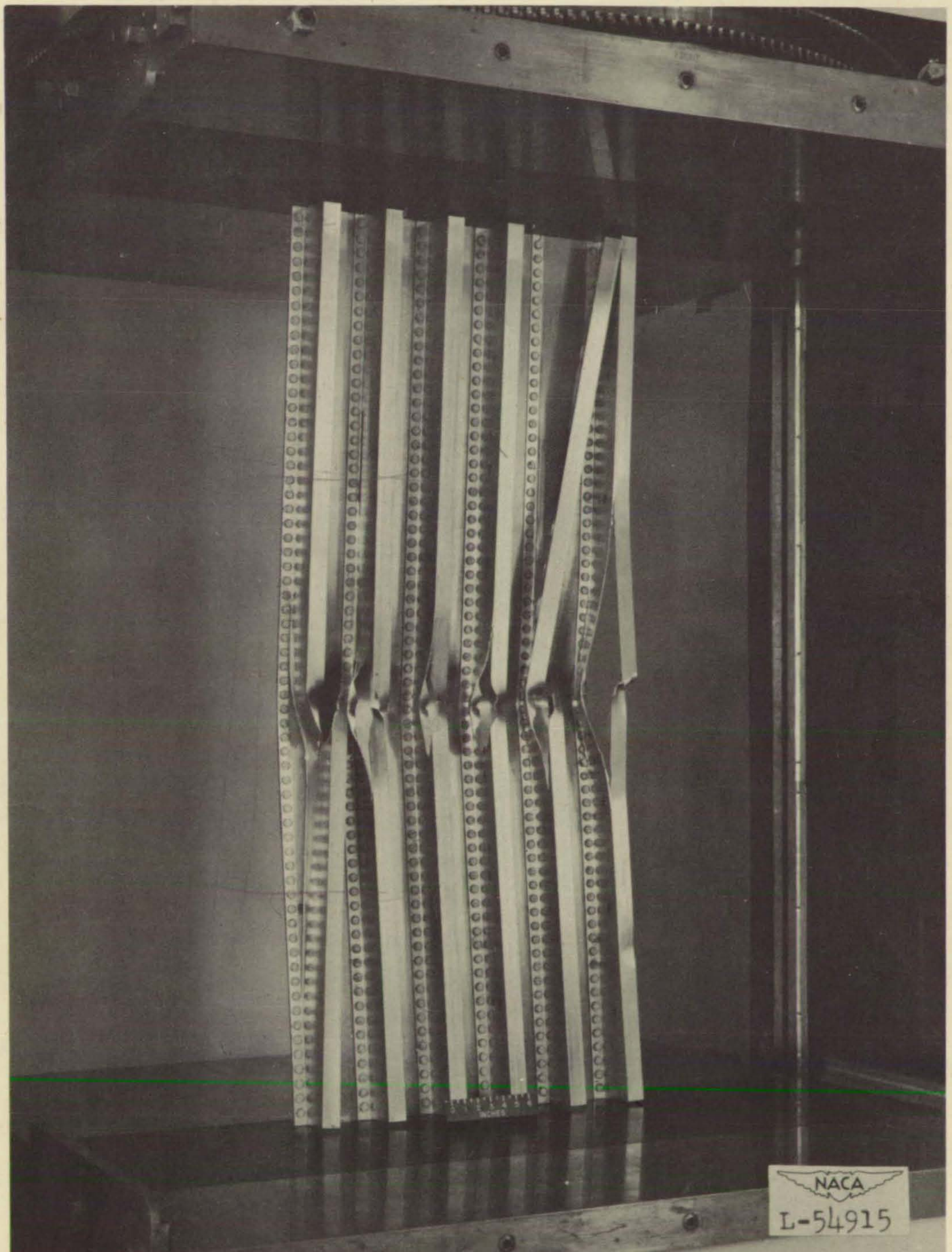

Figure 2.— Panel after failure.

Page intentionally left blank

Page intentionally left blank

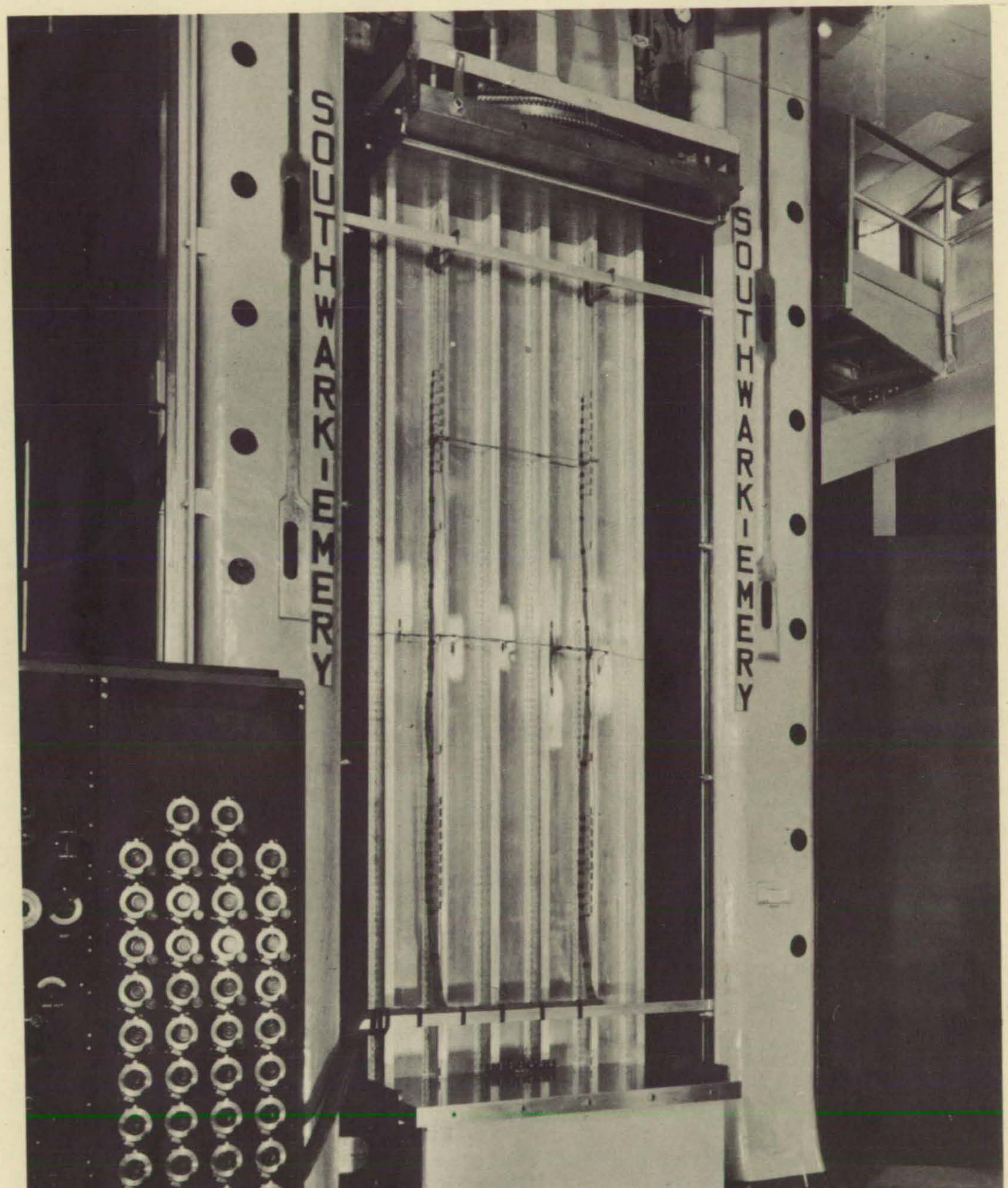

Figure 3.- End-fixity test.

Page intentionally left blank

Page intentionally left blank

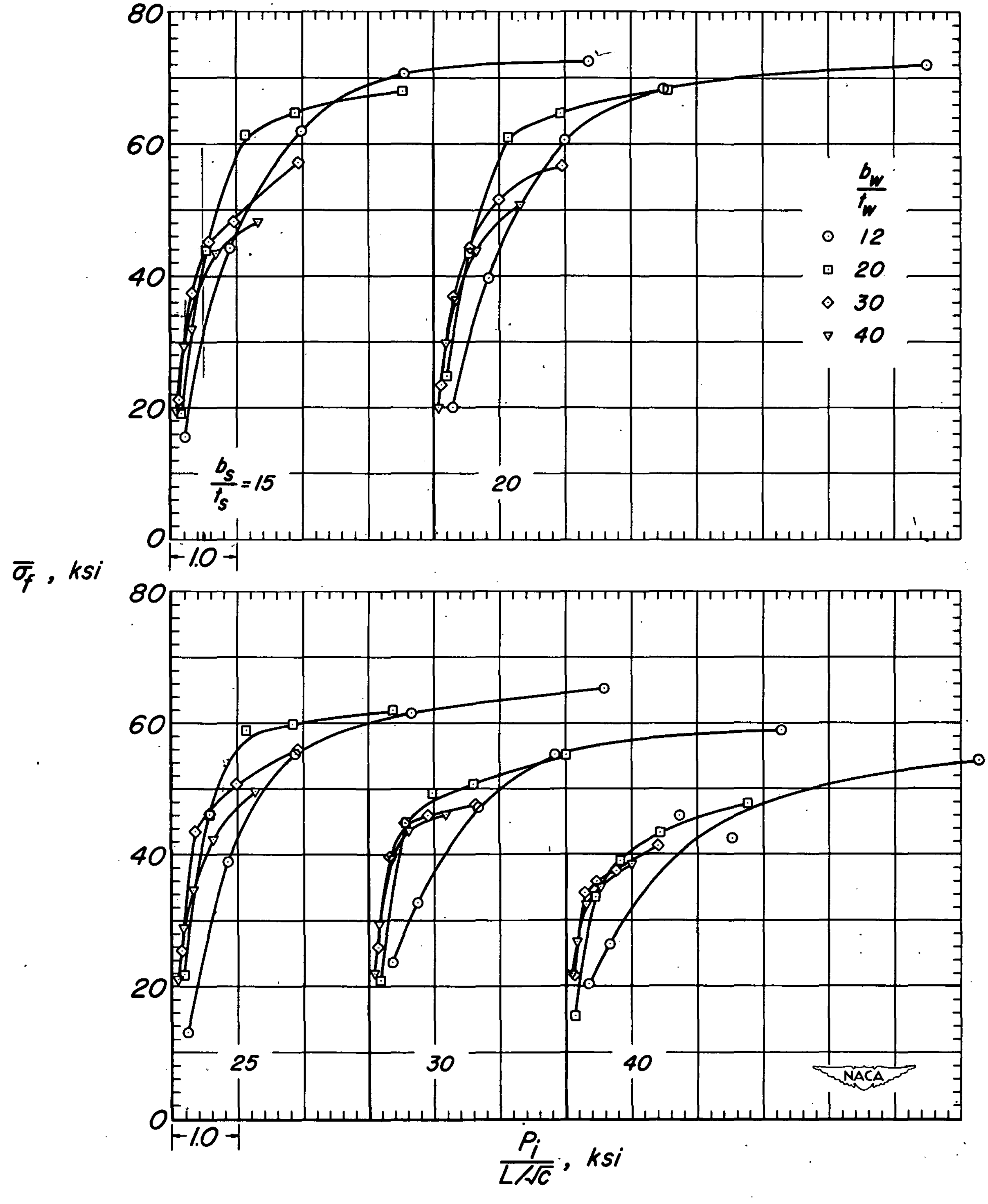

Figure 4.– Compressive strength of 75S-T6 aluminum-alloy flat panels with extruded Z-section stiffeners; $\frac{t_w}{t_s}$ = 0.40.

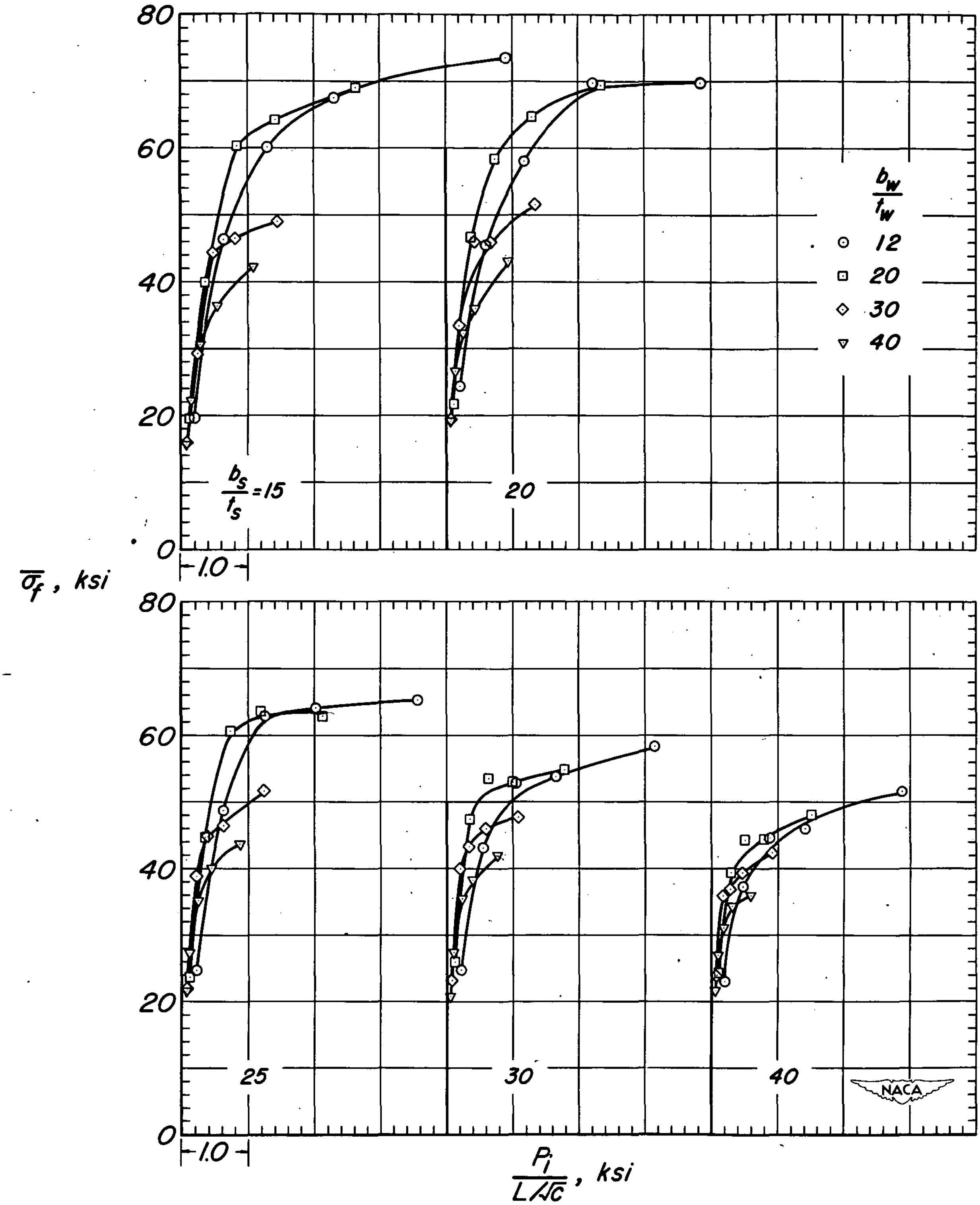

Figure 5.- Compressive strength of 75S-T6 aluminum-alloy flat panels with extruded Z-section stiffeners; $\frac{t_w}{t_s}=0.63$.

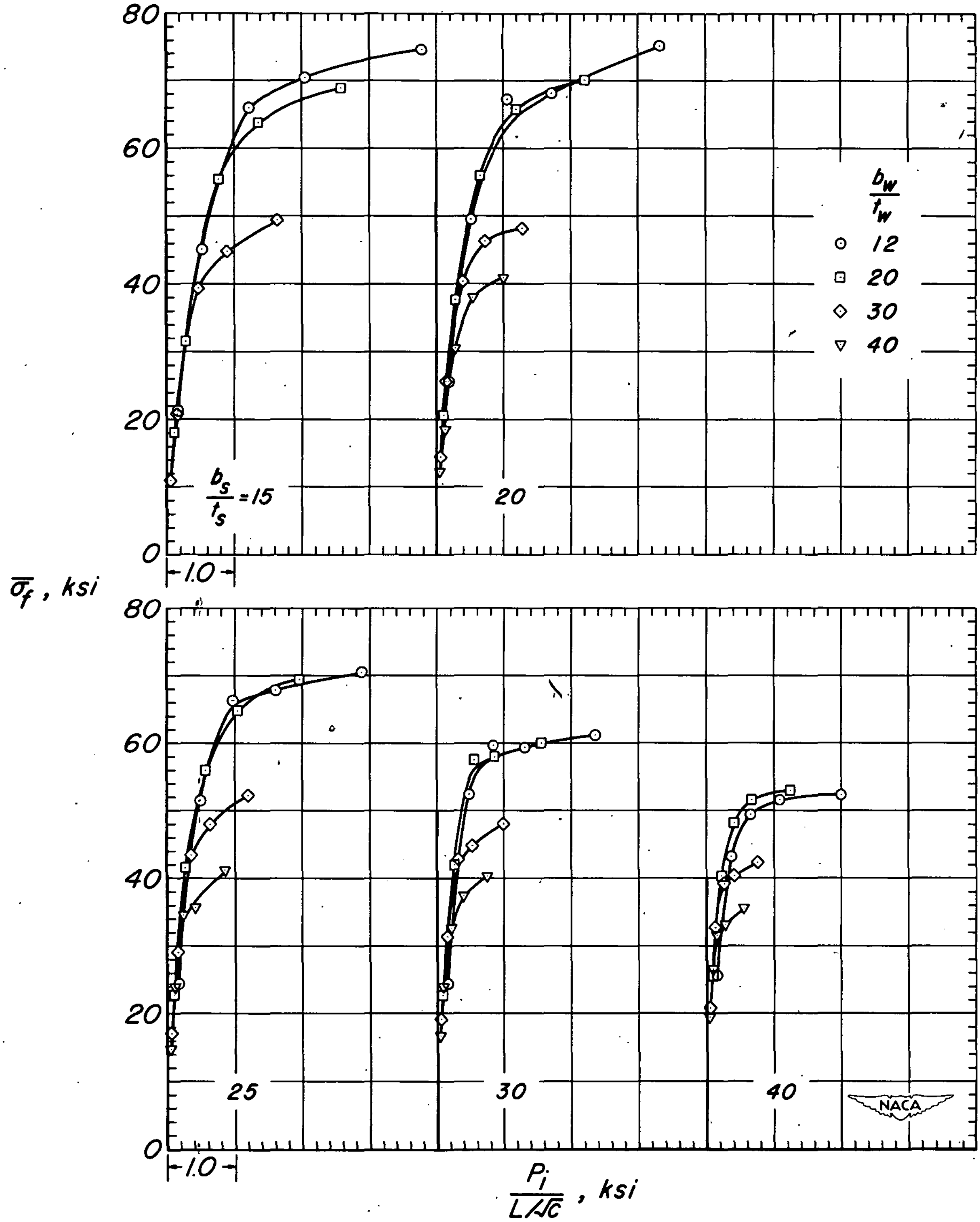

Figure 6.– Compressive strength of 75S-T6 aluminum-alloy flat panels with extruded Z-section stiffeners; $\frac{t_w}{t_s}$ = 1.00.